(12) UK Patent Application (19) GB (11) 2 158 942 A

(43) Application published 20 Nov 1985

(21) Application No 8512214

(22) Date of filing 14 May 1985

(30) Priority data
(31) 8412832 (32) 18 May 1984 (33) GB

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(51) INT CL[4]
G01J 1/56

(52) Domestic classification
G1A A1 A2 A3 A6 D10 D11 D6 G12 G15 G1 G2 G7
HP P15 P16 P1 P2 R7 RT S4 T14 T15 T20 T21 T3 T8
U1S 1673 1909 G1A

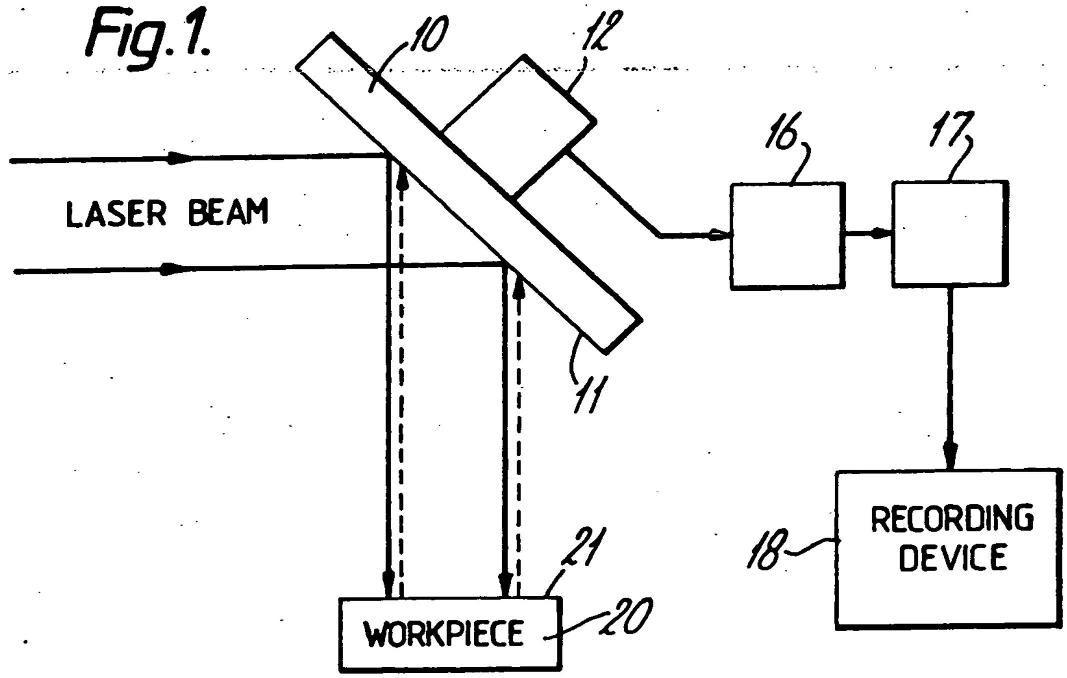
(56) Documents cited
US 3531210

(58) Field of search
G1A
G1N
G1U

(54) Electromagnetic radiation detector

(57) A predetermined characteristic of a beam of electromagnetic radiation, in particular a laser beam, is detected by disposing a reflector (11) in the path of the beam and coupling an electromechanical transducer (12) to the reflector to detect a mechanical response of the reflector to the incident beam. The predetermined characteristic of the beam may be the total power or power distribution of the beam. The surface quality of the reflector (11) may also be monitored. The system may be used to monitor a weld on a workpiece (20), the laser beam being reflected by or transmitted through the workpiece. The transducer (12) responds to mechanical stress waves induced in the reflector by the incident beam.

Fig. 1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1.

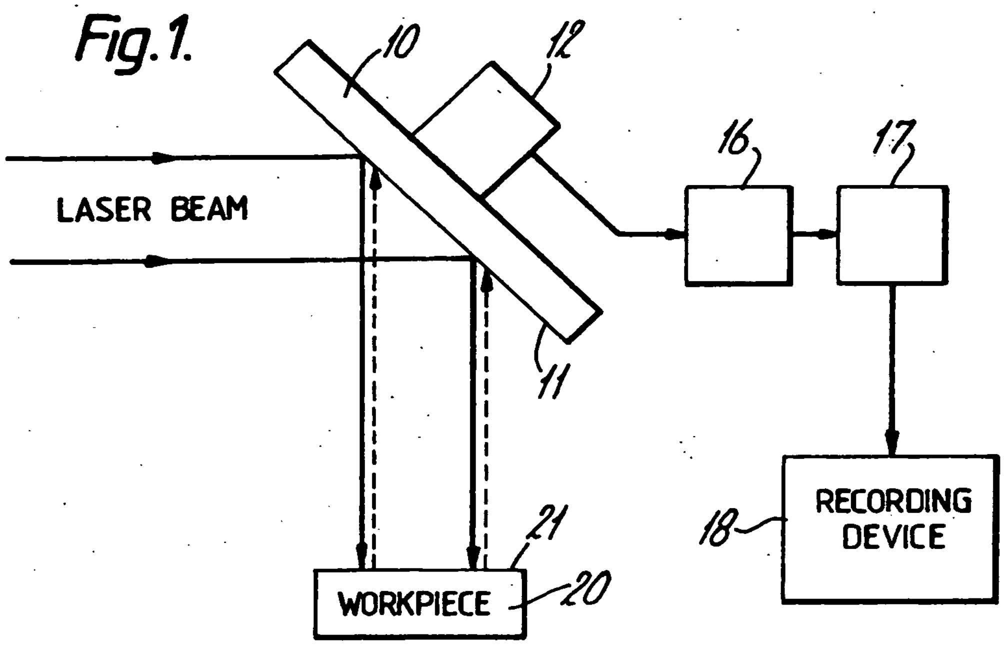

10
12
LASER BEAM
16
17
11
21
WORKPIECE
20
18
RECORDING DEVICE

Fig. 2.

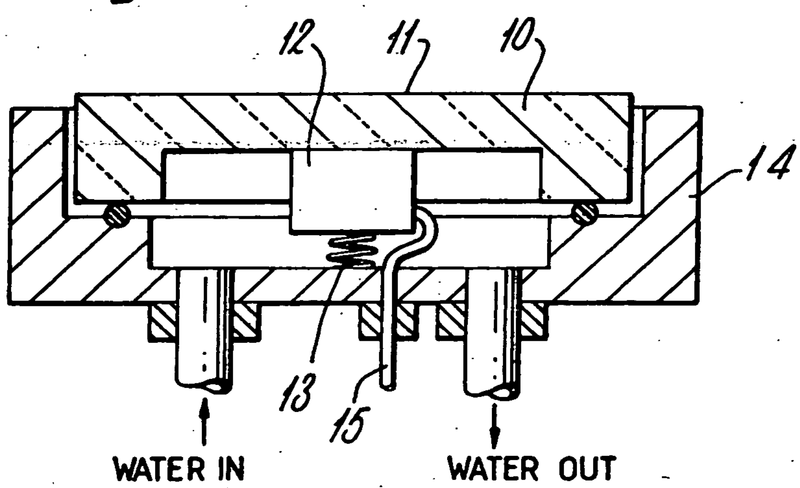
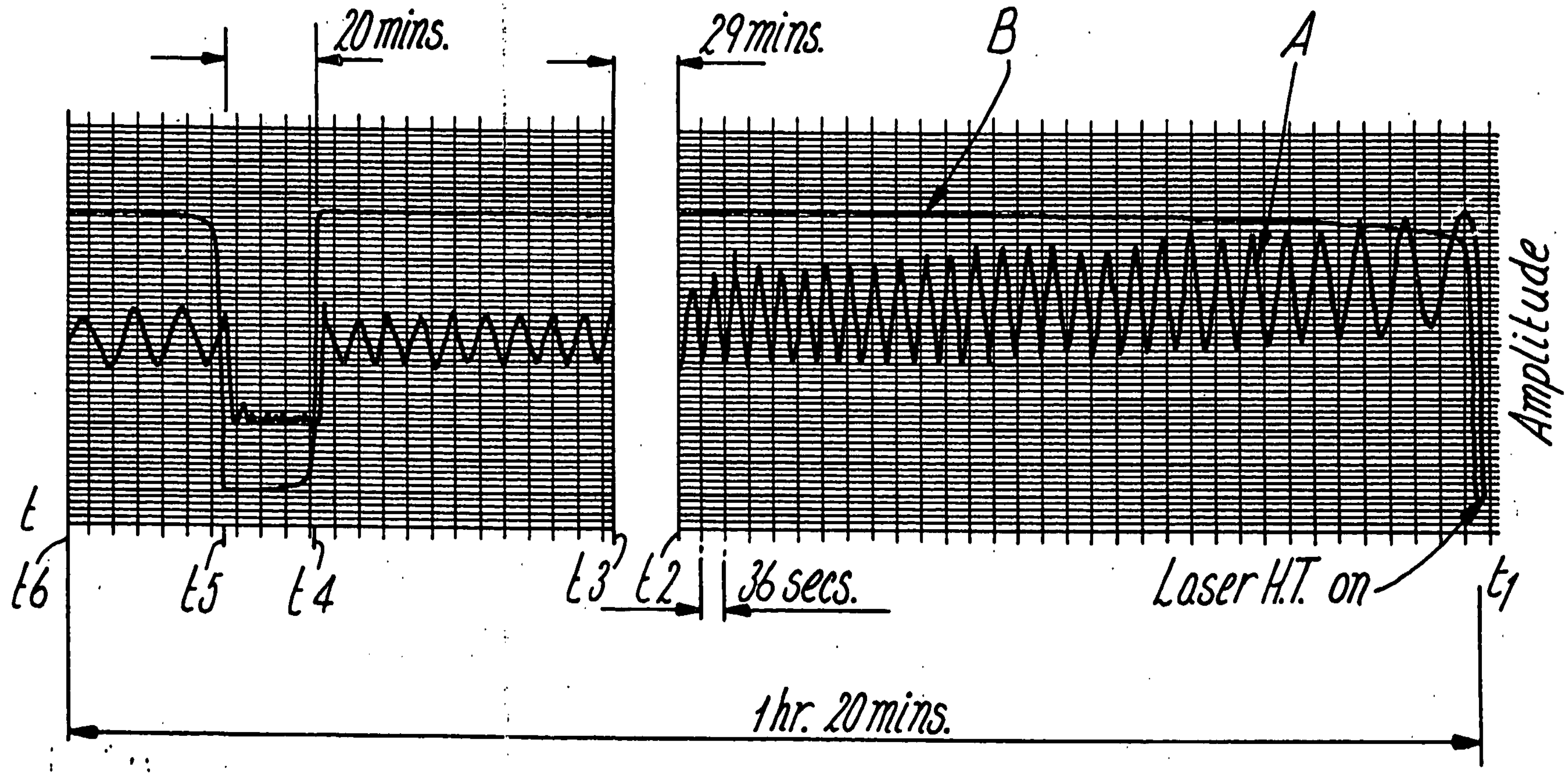

12
11
10
14
13
15
WATER IN
WATER OUT

Fig. 3.



20 mins.
29 mins.
B
A
Amplitude
t
t6
t5
t4
t3
t2
36 secs.
Laser H.T. on
t1
1 hr. 20 mins.

SPECIFICATION

Electromagnetic radiation detectors

This invention concerns the detection of electromagnetic radiation, particularly measurement of the total power or power distribution in a high powered laser beam.

The measurement of the total power in a high powered laser beam is usually done by stopping the beam in a calorimeter as described, for example, in the article by Davies and Peter "Applied Optics" Vol. 10, No. 8, August 1971, pp 1959/60. Such measurements can only be made, however, when the beam is not being used, and this technique is therefore unsuitable for current production processes where the laser beam is "on" almost continuously.

In-process beam measurement can be made using either a beam splitter or a semi-transparent "back-end" mirror in the laser cavity, but both these methods take a measurable fraction of the laser power for their signal generation. One recent alternative is the use of a flying wire or chopper blade which intermittently reflects a small percentage of the beam to a detector. The resulting signal is usually in the form of a power profile, and it represents a measurable loss of power. Moreover, 25 particularly with chopper blades, it also introduces a pulse into a continuous power beam.

Other proposals have included the use of thermocouples for measuring the temperature field generated by the laser on a thin mirror (US Patent 3,738,168), the use of gas expansion tubes or chambers placed in the beam path (US Patents 4,325,252, 4,381,148 and 3,487,685), and the use of pyroelectric detecters (Charschan—Lasers in Industry pp 567–569)

None of these proposals have been entirely satisfactory. Devices such as those described in US Patent 3,738,168, which rely upon measuring the heating effect of the laser beam on a mirror generally suffer from high thermal inertia so that measurements represent the power integrated over a period of time dependent on the bulk of the mirror. They may also suffer from blurred beam images due to the spread within the mirror body. If the devices are limited to thin mirros then as a rule they are also limited to lower power densities. Devices which detect gas pressure generally require either pulsed lasers to generate pressure variations (US Patent 4,325,252), means for modulating the gas composition (US Patents 4,381,148), or a closed gas chamber in which the pressure steadly rises (US Patent 3,487,685). The use of pyroelectric detectors reqires a chopped signal to avoid heating of the ferroelectric.

One final proposal, as described in UK Patent 1,127,818, has been to use the charge effect induced in a piezoelectric crystal when illuminated by electromagnetic radiation. As with calorimeters, however, such devices block the beam and could not therefore be used for in process measurements. Moreover they could handle only relatively low power densities.

An object of the present invention, therefore, is to provide a more satisfactory and versatile device which overcomes at least some of these drawbacks but which at the same time is simple to manufacture and has a fast response time.

According to the present invention a method of detecting a predetermined characteristic of a beam of electromagnetic radiation comprises locating a reflector in the path of the beam and detecting a mechanical response of the reflector to a high frequency signal in the incident beam. Apparatus embodying the invention thus comprises a reflector for reflecting the beam of radiation and an electromechanical transducer responsive to the beam striking the reflector for providing an output signal dependent on the said characteristic.

The transducer is preferably a pressure sensitive transducer for detecting periodic vibrations induced in the reflector by the incident beam. The reflector may be part of the normal beam handling system.

The beam characteristic may, for example, comprise the power density, and we have found this can be monitored by measuring the voltage level and/or the frequency of the output signal obtained from the transducer.

The performance of the reflector is not affected by the measurement, and the system is therefore especially suited for in-process measurements. The instrument measures the required beam characteristic with no additional beam interruption, distortion or power loss other than that normally associated with reflecting mirrors.

The reflector responds almost instantaneously to the incident beam and the system therefore has a fast response time. Moreover it is capable of handling high power densities since the transducer itself does not interrogate the beam.

By way of example only, an embodiment of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of a system embodying the invention for monitoring the characteristics of a laser beam,

Figure 2 is a diagrammatic section through the mirror/transducer assembly in the system of Fig. 1, and

Figure 3 is a graphical representation of the signals obtained from the system shown in Figs. 1 and 2.

Referring first to Fig. 2, a totally reflecting mirror 10, consisting for example of a block of coppr having a gold plated or polished

reflecting surface 11, is fitted with a piezoelectric transducer 12. The transducer 12 is urged agains the back of the mirror 10 by a spring 13 and acoustically coupled by means of, for example, vacuum grease.

The back of the mirror 10 is recessed to accommodate the transducer 12 and the whole assembly is mounted within a water-cooled mounting ring 14. The signal from the transducer is fed out on line 15.

As shown schematically in Fig. 1, when a high powered laser beam (>100 W per sq. cm.) strikes the reflecting surface 11, a signal is detected on the transducer 12 and fed to a preamplifier 16, a signal processor 17 and a recording device 18.

The mirror 10 forms part of the normal beam handling system and may comprise a mirror within the laser cavity itself.

The detected signal is shown in Fig. 3 as trace 'A'. It is a high frequency signal (the high frequency oscillations not being visible on the trace) with a fast response time and with a low frequency superimposed signal showing some systematic variation in beam characteristics. The high frequency signal is observed regardless of whether the transducer 12 is located against the rear of the mirror 10 or against the rear of the cooling ring 14. It is not therefore dependent on the heating effect of the laser beam but on mechanical stress waves induced in the mirror, and it is thought these may be due to a beat frequency within the laser beam. The beam is, in effect, knocking on the surface of the mirror and producing a 'ringing' effect.

In some cases the transducer might be coupled to the mirror by a component capable of transmitting the mechanical response of the mirror, the transmitting component comprising, for example, a waveguide or exponential horn.

Fig. 3 shows the signal from the recording device 18 (trace 'A') compared with a signal obtained from a conventional calorimeter measurement (trace 'B'). Fig. 3 is a plot of amplitude against time, over a total period of 1 hr. 20 min., (with a break between t_2 and t_3 during which the signal was not recorded) the laser HT being switched ON at t_1 and being switched OFF at t_6. Between t_4 and t_5 the beam was deflected from the mirror to determine the effect of cooling. No effect was found.

Experiments have shown that the voltage level of the output signal is related to the power of the radiant energy falling on the mirror, either directly from the laser source or after back reflection from a workpiece, and the signal varies according to the size and position of the transducer relative to the beam. The device can therefore be used as a power density meter for monitoring the strength of a laser beam of known diameter over a period of time, or for measurements of the beam size and position, or as a back reflector monitor. A cluster of transducers can be used instead of the single transducer 12 to assist measurement of the beam position.

The signal processor 17 may also analyse the frequency of the detected signal to detect any frequency peaks in the frequency spectrum of the signal, the peaks being related to particular beam and laser cavity characteristics.

If the laser beam is focused, movement of the mirror 11 toward or away from the focal point varies the volage level of the output signal, and this variation can be used to assist correct positioning of a workpiece 20 relative to the focal point.

The output signal also provides an indication of the quality of the reflecting surface and can therefore be used to monitor this quality over a period of time.

Since the output signal is particularly sensitive to the power density of the beam and to back reflections, the inclination of a workpiece surface 21 relativd to a focused beam can be detected if the beam from the workpiece surface is reflected back to the mirror 11. In particular a non-perpendicular workpiece surface will reduce the power density over the mirror 11 and the transducer 12 can detect this reduction to assist in positioning a workpiece perpendicular to the beam. If, for example, the beam is being used a weld monitor, a peak signal may indicate a poor quality weld while the absence of such a signal indicates a good quality weld.

The workpiece 20 may alternatively be positioned upstream of the mirror, the beam striking the mirror having been either reflected from or at least partially transmitted through the workpiece.

Beam profile data can be obtained by incorporating a chopper which allows only sections of the beam to fall on the mirror 11 at any time. In addition, a fixed or variable aperture may block the beam prior to the mirror to allow data on beam diameter or precise location of the beam centre to be taken.

The piezoelectric crystal 12 is matched to the high frequency of the detected signal, this frequency being at least 1 KHz and normally exceeding 10 KHz. A typical value would be 1.5 MHz.

CLAIMS

1. A method of detecting a predetermined characteristic of a beam of electromagnetic radiation, the method comprising locating a reflector in the path of the beam, and detecting a mechanical response of the reflector to a high frequency signal in the incident beam.

2. A method according to claim 1 in which the incident beam is a direct beam from a source of the radiation.

3. A method according to claim 1 in which the incident beam is a beam reflected

from, or transmitted through, a workpiece disposed in the path of the beam, the workpiece being located upstream of the reflector.

4. A method according to claim 1 in which the incident beam is a back reflected beam from a workpiece disposed in the path of the beam downstream of the reflector.

5. Apparatus for detecting a predetermined characteristic of a beam of electromagnetic radiation, the apparatus comprising a reflector for reflecting the radiation, and an electromechanical transducer responsive to the beam striking the reflector for providing an output signal dependent on the said characteristic.

6. Apparatus according to claim 5 in which the transducer is a pressure sensitive transducer.

7. Apparatus according to claim 6 in which the pressure sensitive transducer comprises a piezoelectric crystal.

8. Apparatus according to any one of the claims 5 to 7 in which the transducer is located against a surface of the reflector.

9. Apparatus according to claim 8 in which the transducer is resiliently urged against the surface.

10. Apparatus according to any one of the claims 5 to 9 in which the beam is a laser beam and the reflector is located within the laser cavity.

11. Apparatus according to any one of the claims 5 to 10 further comprising a plurality of the said transducers so arranged that the combined output of the transducers provides an indication of the beam size and/or position.

12. Apparatus according to any one of the claims 5 to 11 further comprising means for detecting the voltage level and/or frequency of the output signal from the transducer.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1985, 4235.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.